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On-Train Broadband Feasibility Study

Abstract

This feasibility study is concerned with broadband installation in Pendoline trains, the fastest passenger trains in Finland. Particularly in environments where people spend a great deal of their time in, there is a growing need for fast Internet connections. During the last few years, the popularity of train travel in Finland has risen steadily, one of the reasons for this being the possibility to effectively utilize travel time. Many of the passengers are able to work with their laptop almost throughout the train journey, but efficient data communication facilities are needed to achieve the level of office work environments.

The participants of this feasibility study included, in addition to the Ministry of Transport and Communications and the Institute of Information Technology at the University of Jyväskylä, a group of IT companies and VR (National Railway of Finland). The feasibility study investigated whether it would be technically possible to introduce on-train broadband and whether this would also be economically feasible. Additionally, a survey was conducted to gauge opinions of train passengers about possible broadband connections. The results of the related questionnaire are included with this report.

There are two different versions of the final report: public and internal. The public version concentrates on technologies that enable broadband and on passengers' opinions related to broadband. The purpose of this report is to familiarize the reader with the introduction of on-train broadband to Finland. The internal version is more detailed in its treatment of broadband utilization and technical assessment.

Keywords

train, broadband, broadband feasibility in trains, Pendoline train, technology

Miscellaneous

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Foreword

During the past few years the Ministry of Transport and Communications of Finland has very widely looked into the various aspects in broadband: technology, consumers and prices. The present study has a practical approach to the subject, it analyses how broadband technology works in practice, particularly on trains where it is a novelty.

The report presents the Finnish rail network and how broadband could be utilised on trains. It discusses the operational aspects of various broadband technologies as well as planned experiments. User opinions were asked of train passengers using a laptop while travelling. The train survey produced important results that will be of good use also in the future.

This type of a report lays a good groundwork for further planning and trying of technologies as well as for exploring ways how to bring more benefits to the consumers. By the time of this report's publication further steps in the project will already have been taken and the companies involved in the study together with a couple of other enterprises in the sector will have started the planning work.

I would like to thank the initiator of this project and chair of the management group Ilari Kotimäki from the University of Jyväskylä for fearlessly following through the project. Thanks are also due to the representatives of the project financiers: Jere Korkki, IBM; Ben Ginman, Intel; Ville Hellman, Suomi Communications; Tapani Rantanen, Finnish Communications Regulatory Authority; and Pirjo Huttunen, VR. Special thanks are due to the project secretary and author of the report Tapio Väärämäki from the University of Jyväskylä. I would also like to thank the representatives of Digita and Orbis, who joined the project at a later stage, as well as my colleague Seppo Öörni from the Ministry's Transport Policy Department for his valuable comments.

The Ministry of Transport and Communications was one of the financiers of the project as well as had a representative in the management group, but the contents and conclusions in the final report are on the sole responsibility of the author.

November 2005

Kari T. Ojala

1. Introduction

Some epochs in the world history have distinctive features. The industrial revolution took hold at the end of the 19th century. Up to that point, the world population had been living in agrarian societies. Industrial development accompanied by many inventions started spreading around the world. Urbanization became part of the change.

In a similar manner, the 20th century may be viewed as the time of information technology revolution and the rise of Internet. It was just over a hundred years ago when people were pondering about what the life would be like without the inventions of that time which had become part of what was considered to be normal life. Today we talk about Internet in a similar vein, wondering how we could live without a computer and Internet. There are not many professions for which the use of computer and Internet would not be or become necessary in the very near future. We value efficiency, and thus, want to live, work, achieve our goals and spend our leisure time as efficiently and profitably as possible. Our time is characterized by centralization. Jobs are to be found in growth centers and bigger urban areas. This means commuting over longer distances and spending more time for it. The idea of utilizing better the time spent on commuting is now gathering momentum. A clear indication of this is the so-called JOJO project (Flexible Work project by the Ministry of Transport and Communication), which tries to find out how to integrate commuting time to the individual's work time. This would basically mean that once the employee turned on his/her laptop, a train traveler in the case of JOJO, the work day would effectively commence.

The use of laptop can be easily justified when we consider working on train. A laptop for many is a welcome travel companion to spend time with during long and often boring trips. For the purpose of writing just a source of power in addition to the laptop battery might be needed, but to be able to work to the full capacity, Internet is needed. Using Internet services through a standard modem is no longer feasible, as the services offered today can hog a lot of bandwidth. An additional problem in trains is caused by becoming disconnected from time to time. Laptops equipped with a GPRS modem are affected the same way as GMS calls, which very often become disconnected in blind spots.

To use a laptop in a train necessitates a broadband connection. Broadband is used to transmit data, and enables the use of information and services in information networks. Internationally, broadband is taken to mean a subscriber connection in which the nominal data transmission speed is at least 256 kbit/s. There are many different broadband technologies that can be used for fixed locations. For a train moving from 100 km/h up to 200 km/hr the choice of broadband technologies is limited. For this reason broadband technologies that are also suitable for mobile use have been developed.

On-train broadband trials have been conducted in different parts of the world, and these will be given some attention in this report also. Various broadband technologies have been employed, but general solutions are still some way off. The so-called bullet trains plying between Brussels and London have a satellite-based broadband connection, but, being costly, the scheme depends heavily on the European Community support in its funding and thus is not suitable as a general solution.

Many things can affect connections in moving trains, and need careful consideration. Today, trains are powered by electricity, and their bodies are well protected. The speed factor is also important. As far as the very north of Europe is concerned, it can be stated, on the basis of Sonera's experiments, that the use of satellites does not seem a practical solution. In this feasibility study we consider on-train broadband solutions, and find out whether on-train broadband is technically possible and economically feasible. In addition, this feasibility study considers the methods by which the introduction of on-train broadband in Finland could be best justified.

2. Finland's railway network

Finnish railway network is quite extensive, and the track reaches most of the Finnish towns of some importance. The Pendolino trains which are the subject of this feasibility study are used, however, only for those sections where the passenger numbers warrant it.

At this point of time, Pendolinos are the most modern trains that belong to VR. They are meant for rapid passenger transport. Travel time is optimized by limited number of stops. The railway map below (Figure 1) gives a good idea about the Finnish railway network and its Pendolino routes.

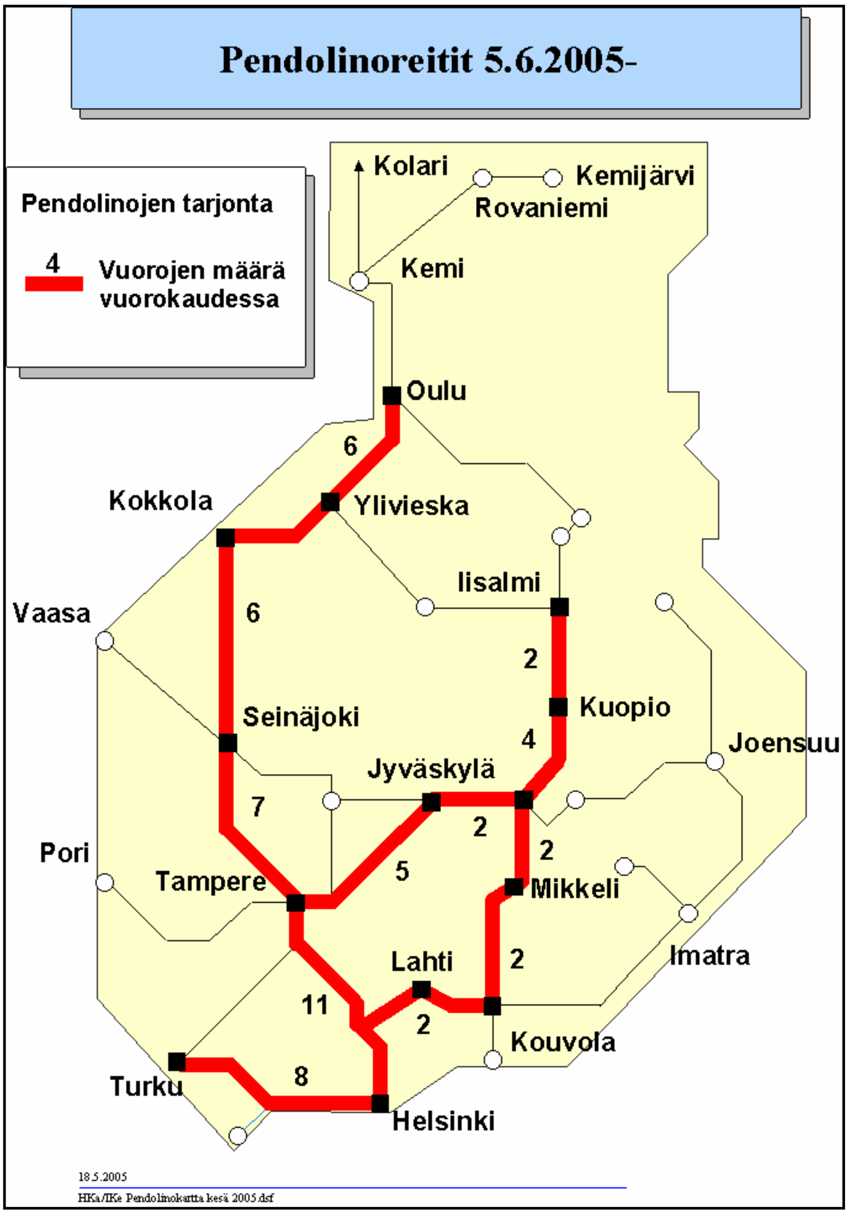


Figure 1. Pendolino routes of the Finnish railway network. Red routes are Pendolino routes. Numbers means number of trips per day.

3. Pendolino train

As stated earlier, the specific subject of this feasibility study concerns installation of broadband in Pendolino trains. Pendolinos are the fastest trains that VR has, and are marketed as means to travel efficiently and rapidly. The tilting system developed for Pendolinos enables them to round curves much faster than is the case with other train types. Another thing to be noted is that there are considerably fewer station stops scheduled for Pendolinos. These two factors that cut travel time ensure that the time used for traveling is shorter than the time used for it by other train types. This is the reason why Pendolinos are very popular with business travelers. Pendolinos are the top trains on the Finnish railways, and thus the most favored choice of VR for on-train broadband Internet connections.

3.1 Train description

The decision to obtain the first Pendolinos in Finland was taken in the so-called "fast train" project which studied the possibility of speeding up Finnish railway traffic with the help of new trains. Trains with a tilting body, Pendolinos, manufactured by the Italian Ferroviaria company (today known as Alstom) proved to be the most efficient alternative to increase train speeds on the existing railway network. It would have been too costly to construct a separate high-speed railway network, and based on the experiments elsewhere in Europe, it should be possible to travel 40% faster using Pendolino than by a typical train through winding railway sections. Apart from Finland, Pendolinos today are also used in other European countries, among them Italy, Spain, the Czech Republic, Slovenia, Portugal and France. The type of Pendolino in use in Finland is SM3.

Pendolinos acquired by Finland since 1994 have been run on the most important railway sections. Suited for fast travel, Pendolinos are composed of units of six carriages, "trainsets", which always remain together, unaltered. This is a great difference when compared with other trains the carriages of which are assembled together for each journey. Pendolino, therefore, is not dismantled except when subjected to maintenance.

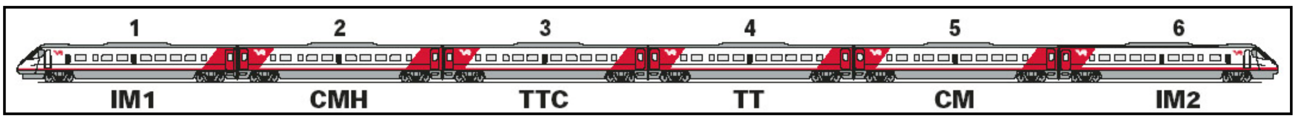
Of the 15 Pendolino units used by VR at the moment, 13 are employed. Each Pendolino is off the track for a day each week during which it is inspected and maintained for the following run period. For the future Lahti direct railway, 3 extra trainsets have been acquired. These will be taken into use in the beginning of 2006, and the direct rail link will be ready in the beginning of September 2006. Currently the number of Pendolino carriages totals 6 x 15 = 90, and after the direct rail link is finished in 2006 this number will increase to 108.

Pendolino's side profile is symmetric. This impression is further strengthened by the fact that there is a driver's cabin at both ends of the train. This means that the train does not need to be turned around when the course is switched to the opposite direction. The maximum speed of Pendolino is 220 km/h, but cannot yet be reached in any railway section. The fastest railway section is between Tampere and Helsinki, where Pendolinos can move at the speed of 200 km/hr almost throughout the whole railway section. The railway link between Lahti and Helsinki will be the first in Finland where speeds of 220 km/h can be reached.

<u>Facts: SM3 Pendolino</u>

Manufacturer: Alstom Ferroviaria
Passenger seats: 309
Carriages per train: 6
Maximum speed: 220km/h
Length: 159m
Height: ~4m (depending on the measurement point)
Weight: 328 tons
Power: 4000 kW
Number: 15kpl
Acquired: First in 1994, the latest already ordered.

Figure 2. A complete Pendolino train



4. Utilization of broadband solution

It would not be economically sensible to install broadband in trains for the benefit of passengers only. It would make more sense to utilize the connection for VR's own purposes as well. A continuously available telecommunications link would enable real time implementation of many of the company's activities.

At the moment trains and their personnel lack proper telecommunication link during train journeys. For example, to transmit sales and reporting information between a train and a station is possible only during the time the train stands at the station. The basic requirement for telecommunications development is a properly functional telecommunication link with which data can be transmitted from the train to stations at an appropriate time. A broadband connection would enable real time telecommunication, and VR expects it to considerably increase the efficiency of its own activities.

The utilization of broadband telecommunications link would not be limited to the development of communications only. To connect the passengers and the train staff, it is necessary to create a wireless local area network within the train. Broadband connection together with the train's internal network can be utilized for countless applications, which might include sales development, safety improvements with the help of video monitoring, or perhaps increasing well-being for the passengers as a result of increased variety of content offering through the video monitors.

A fast and reliable Internet access for the passengers would be an important service, and, according to our survey of train passengers, broadband, were it become available, would significantly improve the opportunities for working in the train. The results of the survey are presented in more detail in Chapter 9.

Apart from making working in trains more effective, Internet access could be used for reading news, for entertainment, or for playing network games. In other words, Internet access in trains, in addition to improving work opportunities would also bring some longed-for variety into train journeys. The possibility of improving voice communications has been considered also.

5. Broadband technologies in current use and experiments with them

There are many different options for using Internet on trains. However, there are great differences in their costs and technical features. It is possible to combine different technological solutions, and in practice aiming at a solution that is optimal cost-wise might involve various technologies. In the chapter that follows we consider some of the differences between these technologies, and pay attention to the aptness and feasibility of each for introducing broadband to trains.

5.1 GSM / GPRS network

There has been GSM (Global System for Mobile communication) and GPRS (General Packet Radio System) networks in Finland since 1991. Today, GSM/GPRS networks cover the whole of Finland leaving only some sparsely populated areas outside their coverage. Due to this extensive coverage of the GSM network, it would be easy to bring telecommunications to trains. The infrastructure for the network is there, and the trains would need only the terminal equipment necessary for the use of the network.

The problem in using the GSM/GPRS networks is their data transmission speed, which is not sufficient for today's telecommunications. Data transmission in GSM networks today is mainly through GPRS, the latter being often referred to as the 2.5G technology. It is a packet based technology intended for data transmissions, and offers a maximum speed of 115 kbps. In practice, the equipment available currently allows speeds between 50 and 80 kbps, which only slightly exceeds the data transmission speed achievable with a normal dial-up phone-line modem.

In some interviews, IBM representatives have talked about experiments with Internet access on trains through the GPRS technology, but the connection speeds have proved to be too slow to make it a practical proposition. IBM had even tried to combine data streams from several GPRS modems, but the connection speed achieved, 200 kbps, would not even then have sufficed for the simultaneous use of several passengers.

VR has also told about its experiments to offer Internet access to train passengers with the help of the GPRS technology. The results of these experiments support those of IBM.

Although the connection speeds achieved by GPRS technology are slow in comparison with those achieved by broadband technologies, it is still a good idea to keep in mind the extensive coverage of the GSM/GPRS network. Trains using broadband as the primary means for accessing Internet might experience problems against which it would be wise to take some precautions. One could think of using GPRS as an alternative means of access to be employed whenever the primary means of connection experienced problems. In addition to this, GPRS technology could be used in railway sections where broadband were not available. This would be necessary for example if it were desirable that the train's sales system and diagnostics could communicate with the VR's information system.

+ The network infrastructure exists, little investment is needed
+ It could act as an alternative technology in problem situations and for railway sections without broadband
- Too slow for the role of "broadband"
- In spite of the extensive coverage of GSM there are areas outside its reach -> can become disconnected (in tunnels, for example)

5.2 Edge network

EDGE (Enhanced Data rates for Global Evolution), known as 2.75G, extends the GPRS technology. With EDGE extensions it is possible to even triple the telecommunication speeds achieved by GPRS. At first, it was thought that EDGE would be strangled between GPRS and 3G. Its future was seen anything but rosy: third generation mobile networks were thought to be the next step of development in telecommunications. Construction of 3G networks proved to be more expensive than expected, and they did not take hold at the rate expected. To satisfy customers eager for faster data transmissions, operators started introducing EDGE extensions to GSM base stations. Today, the EDGE network coverage extends over all the biggest towns in Finland.

In theory, it is possible to achieve a connection speed of 384 kbps by using the EDGE technology, but in practical experiments the connection speeds have remained at the level of 150 kbps. The speed, however, is somewhat higher than that achievable with GPRS.

To implement an EDGE extension, software or equipment updating at GSM base stations is required by the mobile phone operator. Due to updating costs, the EDGE network coverage is restricted to towns and urban areas where the user population is sufficiently large. The EDGE network coverage is just slightly larger than that of 3G, and one can expect this difference to diminish with time. It is probable that the rate of the growth of EDGE will slow down at the same time as the coverage of 3G networks is extended. For this reason, the availability of EDGE technology will be restricted to small areas, and the 3G network will often be available in the same areas. EDGE technology, therefore, does not seem suitable for implementing on-train broadband. Figure 3 shows the coverage of Sonera.

Figure 3. Sonera mobile phone network coverage area.

+ Enables reasonable data transmission speeds at least when several data streams are combined
+ Apart from a terminal the user needs nothing else to use the network
- One EDGE connection is not sufficient for many passengers
- The coverage is restricted to cities and bigger towns, and the operator's interests might not necessarily favor extension of that coverage

5.3. 3G network (UMTS)

Third generation mobile phone networks in Finland are known as UMTS (Universal Mobile Telecommunication Systems). UMTS has been chosen to become the third generation mobile phone standard elsewhere in Europe as well. Only a few years ago it was believed that UMTS would soon extend the "mobile Internet" European-wide, but high subscriber charges, as well as high prices of base stations and terminals have made the spread of UMTS slower than expected. Today the situation seems to be improving, and the coverage of UMTS in Finland extends to almost all bigger towns in Finland. The coverage area map is shown in Figure 9.

Data transmission speed in UMTS networks is considerably higher than in EDGE or GSM/GPRS networks. In theory, the maximum speed is 2 Mbps, put the speed of today's networks is limited at the level of 384 kbps. The transmission speeds decline with the distance from the base station, and the maximum speed is achievable only at the near proximity of the base station. In mobile environments, such as in trains, the highest achievable data transmission speed is 384 kbps.

One reason for the scant popularity that UMTS currently enjoys might be due to high user charges for its data services. Billing based on transferred amount of data significantly increases user costs, often prohibitively. As far as on-train broadband is concerned, pricing based on transmitted amount of data might prove too expensive there as well.

The coverage of the UMTS networks is mainly restricted to city areas, i.e., the UMTS technology is not well positioned to be employed in implementing broadband in trains, at least not as the primary access mode. The UMTS network coverage is slowly and steadily being extended, mainly in urban areas. It will take years to extend it along the railway lines, and at no stage it is thought that it would be extended to cover the whole of Finland.

\+ The fastest mobile phone technology in use (384 kbps)
\+ A possible alternative technology for urban areas
\- User costs prohibitive when transferring large amounts of data
\- Base stations restricted to urban areas
\- Spreading slowly to sparsely populated areas, such as the areas close to railways

5.4 HSPDA and HSUPA technologies

HSDPA (High-Speed Downlink Packet Access) and HSUPA (High-Speed Uplink Packet Access) technologies are extensions to the 3G network, the same way EDGE is an extension to GPRS networks. HSDPA and HSUPA extensions carry the promise of perhaps even trebling the data transmission speed of 3G. HSDPA technology aimed to increase download data transmission speeds is a particularly interesting proposition as regards on-train broadband.

The theoretical maximum speed promised for the HSDPA technology is 14 Mbps, but its real speed will, in practice, be around 300 kbps – 2 Mbps. The first devices conformant with the HSDPA technology will appear in the market by the end of 2005 and in the beginning of 2006.

In spite of the promising data transmission speeds, the potential of HSP technologies is rather limited as far as on-train broadband is concerned. In Finland, HSP extensions can only be implemented at UMTS base stations which are located mainly in urban areas, in towns and cities. Also, it is still questionable how willing would the operators be to invest on HPS updates, since even UMTS services are still behind the hoped-for number of users.

+ High access speeds
- Technology still under development
- Coverage restricted to UMTS base station range in bigger towns and cities

5.5. Wireless local area network (IEEE 802.11a/b/g)

WLAN (Wireless Local Area Network) was originally aimed to connect office computers wirelessly together, but with the development of the technology its applications have been extended to much wider areas.

WLAN technology can be used for example to connect two company units together when it is not possible with fixed cabling. With directional antennas and transmission power used in Europe (100 mW EIRP) it is possible to achieve a fixed point-to-point transmission over a distance of few kilometers. In the United States, where transmission power used can be higher, that distance is often over 10 kilometers. This is, however, possible only when there is a line-of-sight (LOS) between the points connected.

There are three WLAN standards, of which IEEE 802.11b and 802.11g operate in the 2.4 GHz frequency range, and IEEE 802.11a in the 5 GHz frequency range. There are differences between the standards in transmission speeds, modulation, coverage, and approved transmission power. When these standards are used, the maximum speeds of transmission vary between 11 and 54 Mbps, but these speeds, however, apply to the physical layer only. The data transmission itself uses approximately 55 -60 % of the capacity, which means that the maximum speed for the real data is around 5.5 – 24 Mbps.

All wireless local area networks use so-called ISM frequencies (Industry, Scientific, Medical), for which no particular license is needed. License free operation has its downside, however. This becomes apparent when one considers inferences created by low power transmission and parallel systems operating on the same frequency. IEEE 802.11b and 802.11g networks operate in the 2.4 GHz frequency range where the transmission power is restricted to 100 mW. In the 5 GHz frequency range it is possible to use 1 Watt transmission power, but even this is low when compared with the 15 – 60 Watt power level of the GSM base stations. Due to low transmission power, modulation and partially also due to the frequency range used, the use of wireless local area networks over larger distances requires a line-of-sight. The greater the number of obstructions (woods, for example) between the two points, the shorter the distance in-between should be to enable connection.

It is this requirement for line-of-sight, especially, that makes the use of wireless local area networks for the implementation of on-train broadband challenging. GSM masts in the neighborhoods of railway tracks are located too far from the track, the trees growing close to the track and blocking the line-of-sight. This would make the sides of the track the only feasible site for base stations where connection could then be brought by optical fiber. Railway windings are also problematic: base stations would need to be located quite close to each other increasing the costs significantly.

There might be a place for WLAN as an implementation technology for on-train broadband in environments where the use of other technologies was not possible or proved too expensive. This would be the case for example in the neighborhoods of railway stations. This technology is inexpensive, and good data transmission speeds are possible where the access point is stationary or moving slowly. Over longer distances, however, the use of WLAN is not recommended, since similar techniques with longer range already exist.

+ Fast
+ Inexpensive equipment
- Without a line-of-sight operational only over short distances
- Transmission power level limitations

5.6 WiMAX network (IEEE 802.16)

WiMAX (Worldwide Interoperability for Microwave Access) is 802.16 technology standardized by IEEE, and regarded as being especially well suited for long distance wireless telecommunications systems. One of the part standards of WiMAX is now completed, and the tests have shown that connection can be effected also without a line-of-sight, even over a reasonable long communication distance. The operation of WiMAX is similar to the operation of wireless local area networks in that in the middle of the network there is a base station with which the network terminals communicate. It differs from them in its licensing requirements, i.e., setting up a WiMAX network is license-based.

WiMAX technology consists of part standards the best known of which is the 802.16-2004 that is already approved. It is a technology designed for fixed access points, and the devices conformant to it currently operate mainly in the 3.5 GHz frequency range. Other frequency ranges planned for WiMAX technology include 5.8 GHz and 2.5 GHz. The problem is that the availability of frequency ranges varies nationally, and the use of the same frequency ranges in all the countries won't be possible. At least for the time being, in Finland the only frequency range allocated to WiMAX is 3.5 GHz.

The greatest advantage of WiMax technology over wireless local area network technologies is its suitability in forming wireless communication links even where a line-of-sight between the access points is lacking. This is partially due to the modulation technique used, but also to the fact that, in Finland, the only statute that governs the power level in the 3.5 GHz range is that "Radio waves must not induce alterations in a human body."

Although, for the time being, this technology is clearly more expensive than the wireless local network technology, WiMAX's advantage when considering on-train broadband is the large coverage that can be achieved with a single base station. Experts participating in this feasibility study have stated that according to their own experiments the range of WiMAX technology is around five kilometers in circumstances in which there are wooded areas between the base station and the terminal. Its line-of-sight range reach can be tens of kilometers, but one must remember that in the case of trains line-of-sight is a temporary phenomenon.

The maximum access speed achievable with WiMAX technology is 75 Mbps, but as is the case with the other technologies as well, the maximum speed requires optimal conditions. As far as trains are concerned, it is not possible to estimate the exact connection speed, because exact radio-technical modeling of the train environment is difficult if not impossible. Experts participating in the feasibility study estimate that the connection speed would be between 1 and 3 Mbps.

There are many different standards of WiMAX technology, and the standard related to mobile environments, IEEE 802.16e will be completed by the end of 2005. WiMAX devices currently in the market conformant to the 802.16-2004 standard are designed for fixed connections and do not support handover between base stations. Handover between base stations can, however, be implemented manually, and there is, for example in the UK, a functional WiMAX network for train use based on this principle. The incompleteness of the WiMAX standard meant for mobile environments does not necessarily prevent its use in the implementation of on-train broadband. On the contrary, it might be seen as a fairly potential alternative for that.

Base stations could be located in GSM and radio masts surrounding the railway track. Although WiMAX devices are still expensive compared with the terminals of wireless local area network, it is to be expected that the prices will decrease with mass production. WiMAX Forum is an organization in charge of ensuring the compatibility of various manufacturers' WiMAX equipment. It already has constructed a test laboratory where the aim is to test the compatibility of WiMAX equipment. Once the tests have been completed, and if the results turn out to be acceptable, the tested equipment will be given a WiMAX certificate which guarantees its compatibility with other WiMAX equipment. Having obtained the certificate for their equipment, the manufacturers can start mass production. First tests in the laboratory are scheduled for the summer 2005.

The expectations for WiMAX technology have been raised by publicity given to it long before the publication of the standards. It is the consumers, though, who have the final say as regards the status of WiMAX in the wireless telecommunication market. WiMAX technology is backed by many large ICT companies, and there is a lot on stake here for them. If these companies succeed in their aims, WiMAX will become a widespread technology. This would be indicated by low prices of terminal equipment and strong equipment development.

+ No line-of-sight required
+ Good transmission speeds
- The development of WiMAX standard for mobile use is still incomplete

5.7 Technologies suitable for the 450MHz range

Technologies suitable for data use within the 450 MHz frequency range include Flash-OFDM, and CDMA2000 (CDMA450). Neither of these has been developed solely for the 450 MHz frequency range, and terminal equipment conformant with these technologies is now available for many different frequency ranges. In the Nordic countries as well as in some other European countries the 450 MHz frequency range has been allocated for wireless data use, for example to introduce broadband to sparsely populated areas. For this, the frequency range in question suits perfectly due to the excellent reach of its signal. None of the 450 MHz license applicants in Finland has indicated having any intention to use TD-CDMA technology, and for this reason, it is not dealt with here either.

Flash-OFDM and the CDMA450 technologies differ greatly from each other. Flash-OFDM, keeping in mind packet switching that it employs, has been developed to become completely IP based, whereas the CDMA450 technology is based on mobile phone architecture. For this reason there are some differences in these networks' operations.

In spite of this, the data transmission speeds achieved by both of these technologies are at par with each other. Flash-OFDM enables, on an average, data transmission speeds of 1 – 1.5 Mbps from the base station to the user, whereas in the case of CDMA450 this speed is 0.6 – 2 Mbps. The theoretical download speed for both of these technologies exceeds 3 Mbps. The biggest differences arise in uploading speeds. This speed for the Flash-OFDM technology is 0.7 Mbps at the maximum, while for the CDMA450 it is 0.2 Mbps.

Apart from these differences in data transmission, there are differences in practical operations. Packet switching in Flash-OFDM technology enables, among other things, better prioritizing of traffic. It is particularly useful when the network becomes congested. Another advantage of Flash-OFDM when compared with CDMA450 is its shorter network response time: for Flash-OFDM it is 50 – 70 milliseconds, on an average, whereas for CDMA450 it is 150 – 250 milliseconds. There are differences between these technologies in the time it takes to activate the connection. In CDMA450 there are two stages in the connection activation, whereas in Flash-OFDM three stages have been allocated. Due to this 3-stage connection activation, Flash-OCDM connections, in certain circumstances, are activated slightly faster than in the CDMA450 technology. The number of users simultaneously being able to use the network within the range of a single antenna is approximately 125 with the Flash-OFDM, whereas with CDMA450 the corresponding number is 16 -30. Both of these technologies support handover from one base station to the other and use in mobile environments.

In Finland, Digita is the only operator with a license to construct a digital mobile communication network operating in the 450 MHz frequency range. It can provide both mobile communication and data transmission services. As a condition to grant the license the applicants were required to construct network especially for the areas where broadband was not available. The applicants, however, are of the opinion that building a network to cover only sparsely populated areas is not a feasible business model. All the operators that applied for the license emphasized that they would extend the network across the whole country, in which case the network would also flank the railways.

The Ministry of Transport and Communication stipulates in granting the license that the network should be built using, first and foremost, the technology proposed by the applicant wherever possible. The use of other technologies would not be allowed as that would require making alterations to the license granted by the ministry. Also, Digita intends to make the network coverage area as wide in extent and population coverage as possible, which means that using different technologies would not be efficient in business terms.

To use the future mobile communication network in the 450 frequency range would require only that the user had suitable terminal equipment available. Cellular rays of the network should carry up to 20 km, and the signal should be detectable far away from the base station. If the Flash-OFDM network could be received also along the railways, it could be regarded as an efficient tool for on-train broadband implementation.

Initially the area of network coverage will be planned primarily for the benefit of non-mobile environments. The technology makes it possible to use it in speeds of up to 250 km/h in mobile environments, but to make it reliable for mobile use it must be supplemented by additional base stations and antennas. The greatest investments when building the network are due to the construction of the basic infrastructure, after which the optimization of reception for example for the railways would become less expensive. In future, network reception can be measured with practical testing.

The biggest weakness the 450 MHz mobile communication network has in comparison with the WiMAX technology is its lower speed and lower data transmission capacity which both are due to its smaller frequency band. Overseas, Flash-OFDM technology has been trialed in the 5 MHz frequency band resulting in significantly higher data transmission speeds. The limited capacity of the network has, therefore, nothing much to do with the Flash-OFDM technology itself but is due to the narrowness of the frequency band allocated to Digita.

With many network users there is a clear danger of congestion. During the first stages of the network construction more emphasis will be put on the coverage than on the data transmission capacity. This will result in great cell sizes, and a single cell might cover wide areas. In urban areas, such as in towns and cities, the number of users might be too high, reducing thus user-specific transmission speeds.

+ Good signal reach in the 450 MHz frequency range
+ The network will be constructed regardless, investments small
- Small frequency band limiting wireless data transmission

5.8 Satellite link

Swedish Icomera and Canadian PointShot offer satellite based solution for on-train broadband. The use of satellites in the implementation of broadband for trains seems to have its merits in that there would be no need to build a separate network infrastructure at all; it would suffice that the trains were equipped with satellite receivers. When considering satellite based solutions one needs to remember, however, that satellite connection would function only downstream, and for uploading one would need to use GPRS for example. It is possible to use satellites for upstream traffic as well, but the equipment needed for that would not be cost-efficient for trains, at least not for the time being. Two-way satellite traffic is also considerably more expensive, and the amount of upload data being much less than the amount of download data does not warrant such a highly efficient system.

Today it is possible, using a satellite link, to reach a maximum data transmission speed of 10 Mbps, which is sufficient for the purpose of on-train broadband. It is also possible, by combining several satellite links, to increase the speed, but even using a single satellite link alone is costly. Satellite usage charges increase with the connection speed, and it is not cost-efficient to use speeds exceeding 1 Mbps.

Telecommunication satellites are positioned in geosynchronous (GEO) orbits at the height of 36 000 kilometers. There is a 240 milliseconds delay created by the signal having to travel from the earth to the satellite and back again. If a GPRS network is used as the upload channel, the system will, as a result, experience an extra 300 – 400 milliseconds delay. The delay time in satellite based systems is thus much longer than in other systems. This delay time affects all the applications. An everyday Internet user experiences this delay as a considerable increase in waiting time.

Because satellites orbit the earth above the equator, the further north one is stationed, the lower on the horizon the receiver must be aimed. For this reason, satellite based solutions with Icomera's satellites are not a viable option north of Jyväskylä. Icomera, however, is confident that the connection can function everywhere in Finland with satellites that are dedicated for serving the deep north.

Sonera [1] has told about its testing the use of satellite receivers to bring broadband to sparsely populated areas. Satellites used in these tests had been directed towards the northern areas, and the connection was achieved even in Finland's northernmost parts. Although the satellites had been specifically aimed for the northern areas, receivers had to be directed low on the horizon. According to Sonera, the angle of elevation of the satellite receiver is approximately 15 degrees at the latitude of Jyväskylä. This means that getting a line-of-sight to the satellite from a fixed location may become problematic, and even more so if we consider a train moving through forests.

Each Pendolino train, being an integral trainset with a fixed locomotive, would need its own satellite receiver. However, the price of such equipment is so high that the investment required would exceed million euros. Although that price also includes the train's internal network equipment, it is nevertheless very high. Yearly use charges for 1 Mbit speed would be so high that were the money invested in a base station based solution the investment incurred would pay itself back in a few years in a form of savings.

Taking into account the cost and technical estimations together with our northern location one can say that a satellite link does not offer a solution that would justify its use in the implementation of on-train broadband.

+ Up to 10Mbit/s connection speed
+ No network required, a receiver is all that is needed
- Fairly expensive
- Connection uncertain due to the line-of-sight requirement
- Long delay time

5.9 IEEE 802.20 Mobile Broadband Wireless Access technology

The idea behind the IEEE 802.20 standard under development is "vehicular mobility" which refers to broadband in vehicles. The standardization work has not yet been completed, and the aim is to bring it to its completion before the end of 2006 [2]. The schedule might, however, still experience some delays as has been the case with the development of other standards.

The aim of the working group is to create a standard which would require the equipment conformant to it function below the 3.5 GHz frequency range up to the speed of 250 km/h. The promised speed for downstream data transmission is 18 Mbps at the maximum, and the technology would also support handover between base stations.

Because its development is still incomplete, it will take some time before the technology can be implemented, and therefore at the moment 802.20 is not a realistic choice as a technology for on-train broadband implementation.

+A perfect solution for vehicle broadband implementations
- Completed, at the earliest, after 1.5 years
- Implementation of the technology will take even longer

5.10 Utilization of digital TV network

The Ministry of Transport and Communication has published a feasibility study [3], which investigates the possibility of implementing downstream broadband with the help of digital TV network. Digital TV network cannot be used in the implementation of upload direction. Thus Digi-TV-Internet would be required to have the uploading connection implemented with a telephone network. The strong point of Digi-TV-Internet is the large coverage of the digital TV network. It is estimated that by the end of 2006 the digital TV network (DVB-T) will have reached ninety-nine percent of Finnish households.

Related to the feasibility study, a pilot experiment, in which a small test network was built to ensure that the solution investigated would be feasible, was conducted. The maximum data transmission speed reached in the experiment was around 1 Mbps for downloading, while the average speeds were around 256 kbps. It was observed that the equipment was not very reliable in a practical implementation, and was difficult to obtain. Digita has also reported about post-pilot experiments in which the uploading was implemented with the help of a GPRS network instead of an ordinary circuit switched telephone network. When GPRS technology was used, the network delay time was excessive, and the connection was poor. However, network delay time can be controlled with the help of technology. Internet services that are based on satellite links are an indication of this.

With the help of the piloted solution it is possible to create a transmitter-specific distribution band of a few megabits in the currently operated digital TV network. For higher speeds, the network would have to be modified and extended, which presupposes significant economic investments. In Finland at least it is very unlikely that any modification work would commence, because it is just a question of time when the building of a nationwide mobile communication network for the 450 MHz frequency range will start. It makes no sense to construct several networks for the same purpose. The future 450 MHz mobile communication network is better suited for Internet than the digital TV network, having a better uploading channel due to its better overall implementation.

DVB-T network cannot be used in mobile environments, because the technology has been developed with fixed locations in mind. The network coverage is planned with the assumption that the receiver is equipped with a directional antenna. However, the use of directional antennas in trains is not feasible, because of the winding parts of the railway system. There are also certain limitations which apply to the reception of signal in mobile environments – however, with the help of diversity antenna, DVB-T can deal with speeds up to 100 km/h. Due to limitations in coverage and technology, the piloted model is unsuitable for on-train broadband implementation.

5.11 Leak cable

Leak cable is a special-purpose cable that can be used, instead of an antenna, to create a radio frequency field in places where it might prove difficult or impossible by other means. As an example of these kinds of places one could think of tunnels and mine pits.

During the last decade the popularity of wireless telecommunication has grown in leaps with the freedom of movement offered by wirelessness. In certain environments the implementation of wireless coverage is nevertheless difficult to achieve, due to heavy concrete and metal walls, for example. Subway tunnels are another good example of such an environment. It is, however, desirable to have a data and mobile phone connection available in these places. A narrow and confined tunnel can be equipped with a leak cable mimicking the functionality of an antenna. The cable radiates a low power radio frequency field into its surroundings. This arrangement differs from an ordinary antenna setup in that a cable can be installed into a very small space and it radiates everywhere where it runs. The cable range however is so short that the target needs to be close to it, otherwise connecting to the network won't be possible. This radiation distance for a wireless local area network is about 10 meters.

With regard to Finnish railway network, leak cables could be used to bring radio connection to tunnels. With the help of leak cables, telecommunication connections can be integrated, and thus there won't be discontinuity in tunnels in this respect.

5.12 Use of several technologies

There are many technologies that may be regarded as suitable for on-train broadband implementation, but environments that are favorable to the use of each differ. For example, the narrow frequency band allocated for Flash-OFDM does not allow great numbers of users within the operational area of a single base station unit. In densely populated areas, in cities and towns for example, network congestion can occur. The optimal use environment in this case would be a sparsely populated area where a low frequency range would guarantee a long reach, and where the numbers of users were limited.

Broadband WiMAX technology enables better data transmission speeds than Flash-OFDM, but a weaker signal range is its downside. WiMAX networks will not have a nationwide coverage like Flash-OFDM. For this reason, urban areas are more optimal for the use of WiMAX.

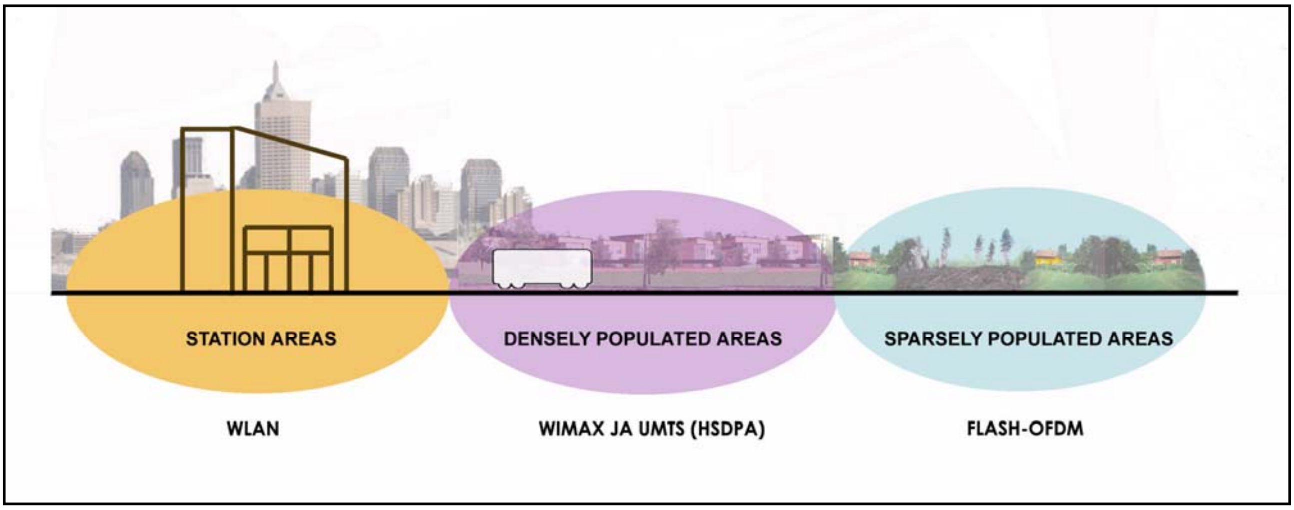
Currently only a few cities and towns have WiMAX networks. In towns without WiMAX it might be possible to use UMTS networks instead of Flash-OFDM, depending on the influence this would have on data transmission speeds. However, it is not easy to estimate data transmission speeds before practical testing. Future HSDPA updates to UMTS networks will significantly increase the data transmission capacity of these networks.

Wireless local area network is particularly well suited for areas with a limited extent. With its help, implementing a large capacity telecommunication network can be quite inexpensive. In train environment, areas with a limited extent but which are roofed are usually restricted to railway stations and tunnels.

The properties presented above determine which technologies are best suited for which environments. It makes sense to use Flash-OFDM technology for sparsely populated areas, whereas WiMAX and UMTS are better for urban areas. Wireless local area network is a good and inexpensive tool for networking small areas such as railway stations.

It is of course possible to use just one technology in broadbanding trains, but when one aims for cost-efficiency the most sensible option would be a hybrid solution incorporating several technologies. This would allow the use of each technology in its favored environment, and the existing network infrastructures could be used as well.

Figure 4. Different technologies suit for different use environments



5.13 Implementations in other parts of the world

Finland is not the only country to set out implementing broadbanding in trains. Around the world different solutions have been applied for the development of on-train telecommunications systems. In the U.K, for example, data transmission speeds of up to 6 Mbps in a moving train have been reached with the help of WiMAX technology.

Southern Trains has broadbanded its London-Brighton fast service rolling stock, believing that Internet broadband access will increase the number of passengers. A survey has found out that many passengers feel that travel time is wasted time, and Southern wants to remedy this. Now many of the passengers inform that they work while commuting, and in this way commuting has become part of their work time.

The bullet train shuttling between France and Belgium at the speed of 300 km/h is broadbanded with a technology based on satellites. This solution by Thalys, the train operator, differs from other satellite connections for trains in that the upload direction is also through satellite access. This kind of solution for trains is unique, and the European Space Agency among others has provided technical support for the construction of the system.

If satellite access is implemented for trains traveling in lower speeds, it is possible to implement the upload direction using technology based on radio networks. In Sweden and in the United States, for example, on-train broadband has been implemented with download from the satellite and upload through GPRS or 3G networks.

6. Access sharing in trains

Although bringing access to trains is clearly the most challenging part in on-train broadband setup, there are certain challenges also in sharing the connection within the train. The connection must span the carriages in spite of the carriages being of compact structure. In Pendolinos, even cabling can be used to run the connection from one carriage to another, but in the case of "normal" carriages that are assembled together, the use of wireless solution is the only option.

As was mentioned in the chapter about the utilization of Internet access, the beneficiaries of broadband access would be both VR and its passengers. This dual usage would presuppose the creation of a separate virtual network for the passengers and VR each. The same physical equipment can underlie both networks, although these would be seen as separate by their users.

Due to high costs, it would be unrealistic to bring Ethernet cabling to each passenger seat. An alternative for cabling is building a wireless local area network which the users would access through their own laptops. The benefits of a wireless network over a wired one are its lower establishment costs and ease of use. Most of the current laptops have WLAN support. Of the respondents to the train questionnaire 76 % stated that their laptops could be used with wireless local area networks.

Using wireless local area network it is possible to establish a fast and reliable telecommunication network inside a train. It would not only cater for the passengers' Internet needs, but it could also be used as a base for designing a video surveillance network. Wirelessness allows freedom of movement for users, and as for the personnel of VR this is a necessity for them in the area covered by the network. When properly implemented, a wireless network is long-lasting and serves users far into the future.

7. Information security

In train broadbanding it is sensible to utilize wireless data transmission systems based on radio networks. However, wireless information networks are vulnerable to eavesdropping of data traffic, which can be regarded as a significant threat to information security also in train broadbanding. In wireless data transmissions radio waves used cannot be hidden from eavesdroppers. Thus the only reliable way to protect wireless communications is encrypt them in such a way that outsiders won't be able to understand them. It is not only the network inside the train that is threatened by eavesdropping; the same threat applies to data communications between the train and the network outside.

Secure communication links for train personnel are especially important, because it is them who need to be able to convey credit card information, for example. It is just as important to protect the passengers' communications, but ultimately each passenger is responsible for the security of his/her terminal equipment.

The same physical equipment can be used in the establishment of both the passengers' as well as the staff's local area networks. This can guarantee a well-implemented information security for both of these networks, and, for example, passenger log-in to the network can be made secure.

Apart from securing the network inside the train, it is also possible to effectively protect communications between the train and the base stations installed along the railway. Strong encryption and authentication, which ensure a good information security level, can be used for base stations and for the train's terminal equipment. This is to say that all communication traffic directed to the network outside can be protected against eavesdropping, enabling transmission of even confidential information in the network. If several different technologies are used in the implementation of trunk connection, it is advisable to use a single protected higher protocol layer as a connection that can be encrypted and protected effectively.

8. Train survey

In the feasibility study train passengers were subjected to a survey, in which they were asked their opinions about the possibility of broadband access and services related to it. The survey took place 30.5-26.6.2005, and all of its results are presented in the following chapters. The survey questionnaire is discussed with the presentation of the responses, and the summarized interpretation is made after the results listing.

8.1 Train survey in detail

ON-TRAIN BROADBAND

PASSENGER SURVEY
30.5 – 26.6.2005

REPORT

BRIEF GIVEN

The goal of the on-train broadband project, to be carried out by the University of Jyväskylä and administered by the Ministry of Transport and Communications, is to investigate and promote broadband on trains. At the same time the project aims to improve working conditions in trains.
A survey forming part of the feasibility study by the University of Jyväskylä was conducted among train passengers. It sought out passengers' opinions about and gauged their interest in the possibility of broadband access and services related to it.

SURVEY REALIZATION

The field work of the survey was conducted during 8.6 -24.6.05 in Pendolino trains in the route Jyväskylä-Helsinki-Jyväskylä.

Two-phase random sampling was used for the train passengers.
The target group (i.e., train passengers with a laptop) represents 70 % of the sample, the rest 30 % of the respondents being potential users. 70 % of the respondents (with a laptop) were selected by interviewing primarily passengers equipped with a laptop. Amongst the selected people were included those who owned a laptop but rarely or never carried it with them. Non-laptop respondents were randomly selected from among all the passengers. A minimum sample of 150 respondents was easily obtained, and the final number of interviews amounted to 167.

RESULTS OF THE QUESTIONNAIRE

Date of publication: 30.6.2005
Replies received: 167

TRAIN TRAVEL

Q1. How often do you travel by train?

	With a laptop		Without a laptop	
	%	number	%	number
1 Daily or almost every day	**19**	23	**2**	1
2 1-3 times per week	**36**	42	**18**	9
3 1-3 times per month	**31**	36	**30**	15
4 2-6 times per year	**13**	15	**46**	23
5 less often	**1**	1	**4**	2
0 no response				
Total	**100**	117	**100**	50

Q2. What is the purpose of your travel?

	With a laptop		Without a laptop	
	%	number	%	number
1 Business	**69**	81	**20**	10
2 Work	**23**	27	**16**	8
3 Study	**4**	4	**22**	11
4 Leisure	**4**	5	**42**	21
0 no response				
Total	**100**	117	**100**	50

Q3. In which class do you travel?

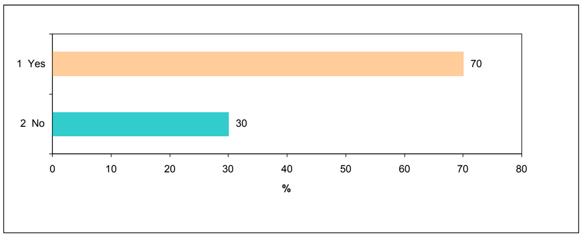
	With a laptop		Without a laptop	
	%	number	%	number
1 1st class	**24**	28	**4**	2
2 2nd class	**76**	89	**96**	48
0 no response				
Total	**100**	117	**100**	50

Q4. How do you usually spend your time when travelling?

	With a laptop		Without a laptop	
	%	number	%	number
1 Working	**73**	86	**10**	5
2 Reading	**20**	23	**48**	24
3 Sleeping	**2**	2	**18**	9
4 Something else? Please, specify.	**3**	4	**20**	10
0 no response	**2**	2	**4**	2
Total	**100**	117	**100**	50

LAPTOP USE DURING TRAIN TRAVEL

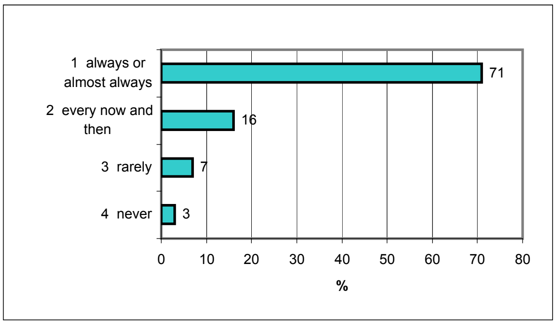
Q5. Do you have a laptop that you could use?



	%	number
1 Yes	**70**	117
2 No	**30**	50
Total	**100**	167

The questions from 6 to 8 are only for those with a laptop.

Q6. Do you use laptop during train travel?



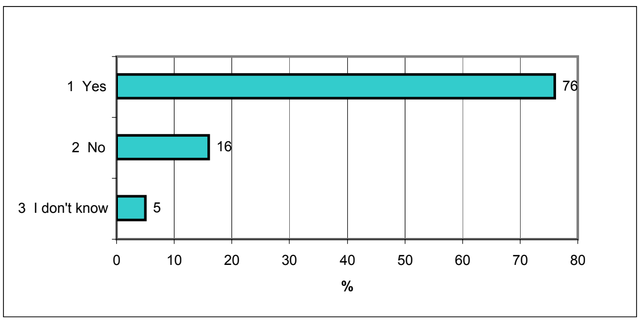
	%	number
1 always or almost always	**71**	83
2 every now and then	**16**	19
3 rarely	**7**	9
4 never	**3**	3
0 no response	**3**	3
Total	**100**	117

Q7. If your response was "rarely" or "never", please explain. (Circle one or more of the alternatives given)

	%	number
1 Not enough plugs	**22**	4
2 Unable to connect	**33**	6
3 Computing security considerations	**6**	1
4 Other reasons? Please, specify.	**39**	7
0 no response		
Total	**100**	18

Other reasons? Please, specify. - The most common responses to this question dealt with travellers' own motivation and poo
For this question the number of respondents was very small (18).

Q8. Is your laptop equipped with WLAN?



	%	number
1 Yes	**76**	89
2 No	**16**	19
3 I don't know	**5**	6
0 no response	**3**	3
Total	**100**	117

SERVICES

Q9. How important do you think are the following services brought out by wireless broadband or the development of the current services? (1=important, 2=somewhat important 3=not very important 4=not at all important)

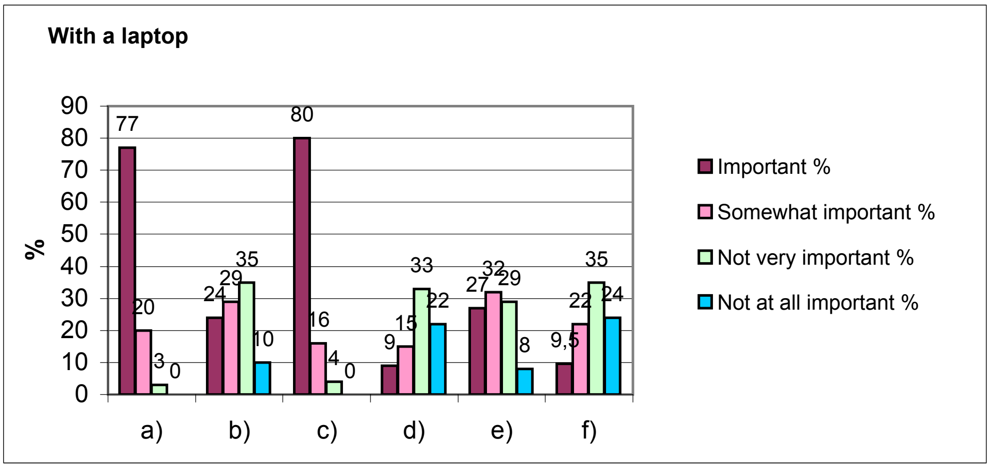
a) Availability of wireless Internet connection in trains
b) Availability of wireless Internet connection in train stations
c) Improvements in GSM reception
d) Availability of VoIP (calls through Internet)
e) Topical information (about stations, for example) through the infomonitors in trains
f) Monitors equipped with touchpads for the use of train travellers

With a laptop

	Important		Somewhat important		Not very important		Not at all important		No opinion	
	%	number	%	number	%	number	%	number	%	number
a)	**77**	90	**20**	23	**3**	4	**0**	0	**0**	0
b)	**24**	28	**29**	34	**35**	41	**10**	12	**2**	2
c)	**80**	94	**16**	19	**4**	4	**0**	0	**0**	0
d)	**9**	10	**15**	18	**33**	39	**22**	26	**21**	24
e)	**27**	31	**32**	38	**29**	34	**8**	9	**4**	5
f)	**9,5**	11	**22**	26	**35**	41	**24**	28	**9,5**	11

Without a laptop

	Important		Somewhat important		Not very important		Not at all important		No opinion	
	%	number	%	number	%	number	%	number	%	number
a)	**34**	17	**26**	13	**22**	11	**10**	5	**8**	4
b)	**22**	11	**20**	10	**30**	15	**18**	9	**10**	5
c)	**64**	32	**24**	12	**8**	4	**4**	2	**0**	0
d)	**2**	1	**16**	8	**14**	7	**22**	11	**46**	23
e)	**40**	20	**34**	17	**20**	10	**4**	2	**2**	1
f)	**6**	3	**46**	23	**26**	13	**16**	8	**6**	3



Wireless internet connections in trains were seen as important almost without an exception. Of the respondents with a laptop 97% and of the respondents without a laptop 60% thought that internet connections in trains were either important or somewhat important.

Internet connections for stations were not seen as important as for trains. Of the respondents with a laptop, 53% regarded wireless Internet connections in stations as important or somewhat important. Some of the responses indicated that connections, if already available at the stations, would not be necessary in trains. Many of the respondents also commented that they spent very little time at stations, and for this reason, did not see it necessary to have a connection there.

Improvements for GSM reception were also thought, almost without an exception, as important. Of the respondents with a laptop 96% and of those without 88% regarded improvements in reception as important or somewhat important.

Availability of VoIP was not seen as very important. Of the respondents with a laptop, 24% thought VoIP as important. It is probable that many of the respondents did not have a clear idea about the content and significance of VoIP calls: of the responses by those with a laptop 21% were "no opinion" and by those without a laptop 46%.

It was also seen as important to put the existing infomonitors in trains into active use. Of the respondents with a laptop 59% and of those without 74% thought that infomonitors were either important or somewhat important. These results reflect the fact that the services in question would, obviously, be more important to passengers without a laptop.

The opinion was evenly divided over the monitors for the use of train passengers. The futuristic idea about a touchpad equipped monitor was regarded as important or somewhat important by 32% of those with a laptop and close to 52% of those without one.

Q10. What is your opinion about Internet connections in trains? Tell in your own words.

Generally speaking, free-form responses showed a very favourable attitude towards Internet connections. Especially those with a laptop emphasized that the availability of Internet connection in trains would not only be important but also necessary. Above all, Internet was seen to be important as far as work was concerned, and the possibility for using email was pointed out as very important in many responses. There were many who believed they could increase their efficient working hours by a few hours even, since it would be possible to start one's working day while still in train.

Some responses strongly emphasized that an Internet connection would bring added value to working conditions only if the connection was sufficiently fast. A slow connection would serve little purpose.

One of the respondents wrote that Internet connection in trains would give the railways a competitive advantage as coaches and other motor vehicles currently lack the connection.

In most of the cases, the respondents who did not have a laptop did no regard Internet connection as important on a personal level. Regardless, connection was viewed as a positive thing.

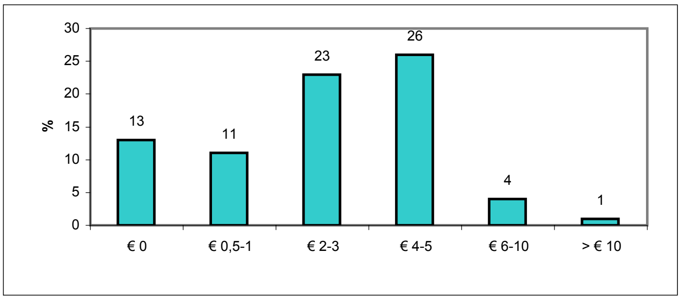
Q11. How much, at most, would you be prepared to pay for Internet connection during a single train trip?

In this, the responses differed greatly, and different opinions about payment methods were suggested. Most thought 2 - 5 euros would be reasonable for a single one-way trip between Tampere and Helsinki. These suggestions ranged from 50 cents up to 20 euros. Many business travellers clarified their statements by saying that the price would not be that important as the company (employer) would pay.

Many of the respondents proposed a special monthly payment system, which would allow the use of Internet for a month for 20 - 40 euros. Some of the passengers thought it a good idea to have the price of the connection included in the fare. Some of the respondents regarded Internet as a service for which there should not be any additional charge. Many 1st class passengers were strongly of the opinion that Internet connection should be included as a service into the price of the 1st class ticket. The 2nd class passengers should, however, be required to pay.

Some of the respondents suggested using cellular operators for billing. One of the respondents proposed charging based on the amount of data transmitted. This form of charging was familiar as it has been commonly used by cellular operators,

Distribution of responses (all respondents):

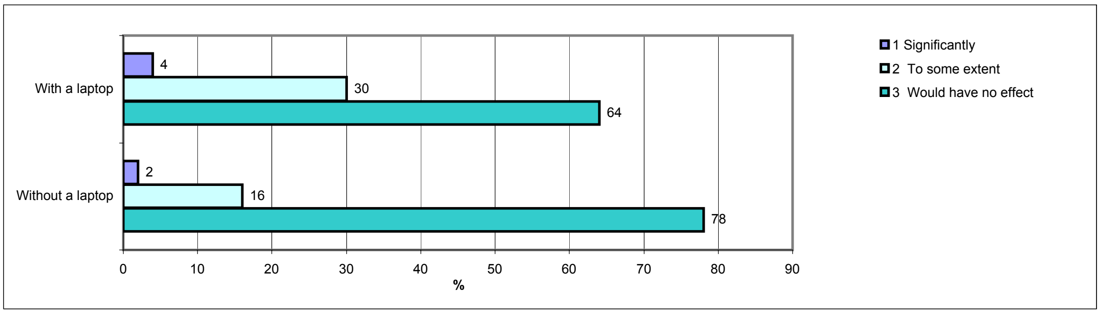


(average:€ 3,16)

	€ 0	€ 0,5-1	€ 2-3	€ 4-5	€ 6-10	> € 10	other	undec.	total
%	**13**	**11**	**23**	**26**	**4**	**1**	**11**	**12**	**100**
number	21	18	38	43	7	1	19	20	167

Q12. Would the availability of broadband services increase your travel by train?

	With a laptop		Without a laptop	
	%	number	%	number
1 Significantly	**4**	5	**2**	1
2 To some extent	**30**	35	**16**	8
3 Would have no effect	**64**	75	**78**	39
0 no response	**2**	2	**4**	2
Total	**100**	117	**100**	50



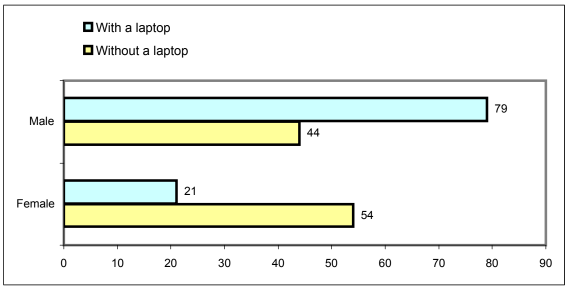
Of the respondents with a laptop 34% believes that Internet connection would increase their train travel significantly or to some extent. The surprising result is that also of those respondents without a laptop 18% thought along these lines.

It should be noted that some of the passengers who already commute by train several times per week would probably not have their rate of travel affected by Internet connection.

BACKGROUND INFORMATION

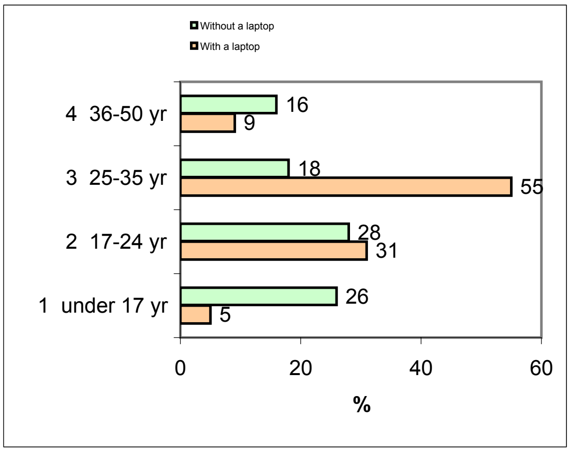
T1 Sex

	With a laptop		Without a laptop	
	%	number	%	number
Male	**79**	93	**44**	22
Female	**21**	24	**54**	27
(0 no response)			**2**	1
Total	**100**	117	**100**	50



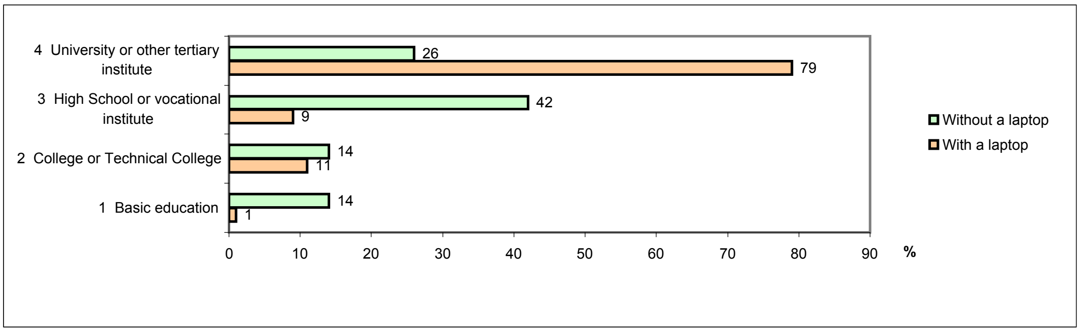
T2 AGE

	With a laptop		Without a laptop	
	%	number	%	number
1 under 17 yr			**8**	4
2 17-24 yr	**5**	6	**26**	13
3 25-35 yr	**31**	36	**28**	14
4 36-50 yr	**55**	64	**18**	9
5 51-65 yr	**9**	11	**16**	8
6 over 65 yr				
(0 no response)			**4**	2
Total	**100**	117	**100**	50



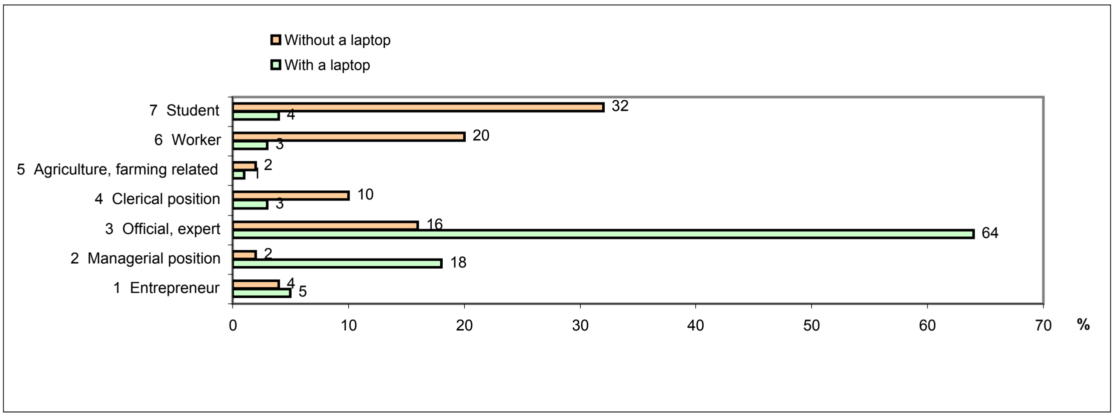
T3 Education

	With a laptop		Without a laptop	
	%	number	%	number
1 Basic education	**1**	1	**14**	7
2 College or Technical College	**11**	13	**14**	7
3 High School or vocational institute	**9**	11	**42**	21
4 University or other tertiary institute	**79**	92	**26**	13
(0 no response)			**4**	2
Total	**100**	117	**100**	50



T4 Occupation

	With a laptop		Without a laptop	
	%	number	%	number
1 Entrepreneur	**5**	6	**4**	2
2 Managerial position	**18**	21	**2**	1
3 Official, expert	**64**	75	**16**	8
4 Clerical position	**3**	4	**10**	5
5 Agriculture, farming related	**1**	1	**2**	1
6 Worker	**3**	3	**20**	10
7 Student	**4**	5	**32**	16
8 Pensioner				
9 Fulltime father/mother				
10 Unemployed	**1**	1	**8**	4
11 Other	**1**	1	**4**	2
(0 no response)			**2**	1
Total	**100**	117	**100**	50



8.2 Discussion of the survey results

On the whole, the survey results reflected a positive attitude towards installing broadband access to trains. Nearly all laptop users wanted broadband Internet access on trains. Their positive attitude was predictable, because almost all of them admitted using laptop for work regularly while commuting. The possibility of Internet access was taken to mean that work conditions in trains would improve further. A surprising number of the respondents without a laptop also wanted Internet access. Some of them were planning to obtain a laptop in a near future.

One of the reasons the respondents regarded train as an efficient means of commuting was that it offered an opportunity for utilizing the time spent on board for work tasks. In free-form responses, many of the laptop owners emphasized the positive effect of broadband access on work possibilities, and some of them even thought that a well-functioning broadband access would allow work at the level of office environment. When describing the desired access properties with their own words, many of the respondents pointed out reliability as an important criterion.

To create a suitable method for possible charging for the use of Internet access is a challenge. The pricing level of the service must be realistic to prevent the service fees shooting up out of the reach of the users. Those wanting Internet access were asked to estimate, in euros, how much they would be prepared to pay for access during a train journey. The responses showed a great diversity of opinions, but the average estimate was slightly over three euros. Quite a few business travelers did not think price that important, since it would be their company that would pay the costs incurred while on train. Regular commuters proposed pricing based on a monthly fee, and thought it might be a simpler way to pay for the access for longer time periods. Some of the respondents suggested a single fee or a daily fee for shorter use periods. Many of the respondents made a strong point about ease-of-use of the payment system and about alternative means of payment. Most of the responses stated that one should be able to make an electronic payment.

Passengers were asked their opinion about different services that could be brought to them by the proposed broadband access. Their opinions were gauged not only about services related to broadband access, but also concerning the possible development needs for GSM reception. Of the laptop owners who had wanted on-train broadband access only a portion wanted the access at railway stations as well. This was clarified by the comments in free-form responses in which it was stated that many of the passengers arrive at the station very shortly before the train's departure. Thus there wouldn't be enough time to use the access point at the station. Neither the laptop owners nor other respondents thought the availability of VoIP important. The majority of both groups of respondents wanted increased content development for video screens, but those without a laptop regarded this more important than the rest of the passengers. The laptop users did not think it necessary to have touchpad equipped monitors, but about a half of the remaining passengers thought that they might find some occasional use for them. Poor GSM reception in trains became evident through the responses: nearly all of respondents wanted improvements in reception.

More than half of both respondent groups surmised that the possibility for broadband access and the related services would not increase their train travel. It should be noted that many of the respondents already habitually use train for most of their travel. This was the case especially with the laptop users. Had this same survey been conducted in service stations at airports and along highways, the distribution of responses might have been a bit more balanced.

Main survey results:

- The opinion was very favorable towards the possibility of broadband access
- Broadband access should be reasonably easy to use
- Reliability in the functioning of broadband access is vital
- Broadband access would significantly improve work conditions on train
- The passengers want improvements in GSM reception

9. Summary

The on-train broadband feasibility study was conducted 15.4 – 31.8.2005. The main funding for the project came from the Ministry of Transport and Communications. The project participants included IBM, Intel, VR, Finnish Communications Regulatory Authority, and Suomi Communications. Our visit to the Uppsala University to meet Prof. Per Gunninberg (Computer Science) there yielded valuable advice. The head of the Bank of Finland, Erkki Liikanen, and the EU Commissioner in Brussels with his whole cabinet deserve our heartfelt thanks for the follow-up funding preparations.

The management group met six times during the project and had two unofficial meetings also. Representatives from the University of Jyväskylä hold telephone discussions with the participants almost daily and met face-to-face with them 26 times. Discussions with Nokia experts were highly regarded. Passenger interviews, highly relevant to the project, were conducted in Pendolinos on the Jyväskylä-Helsinki route in June. The detailed results of that survey can be found in Chapter 9. The expertise of Martta Kyllönen was of great importance for this survey.

The aim of the feasibility study was to answer the questions of whether on-train broadband would be possible and if so whether it would be economically feasible also. Technical know-how for on-train broadband exists already and is developing continuously. In addition to the existing wireless data transmission technologies, countless other technologies that could be used to provide broadband access in mobile environments are emerging. Due to the number of wireless technologies already existing and still under development, it is not a very good idea to use only one technology for on-train broadband. It is possible, of course, but combining different technologies, at least in the case of Finland, one can end up with a more cost-efficient solution. Employing several technologies makes it also possible to use each particular technology in environments that it is best suited for. Suitable candidates for on-train broadband installation today are WLAN, Flash-OFDM, WiMAX, and also, after the future network updates, UMTS.

In theory, bringing broadband to trains might sound simple enough, but in reality to combine several technologies necessitates additional work in the form of practical testing. We need more information related to the functioning of WiMAX and Flash-OFDM in mobile environments before the visions bandied about can be materialized. This is why the feasibility study is to be followed by technical experimentation, in which the functioning of different technologies in a moving train will be investigated.

Although it is possible to find a cost-efficient solution by combining several technologies, installing on-train broadband requires, nevertheless, significant economic investments. To implement broadband for a single railway section alone necessitates building large infrastructure and equipping all Pendolinos with broadband equipment. In short, a fairly significant economic investment is required, and even more is needed when we start talking about nationwide implementation. As for now, it is quite impossible to calculate the exact costs for on-train broadbanding, because, for example, we don't have enough information about how Flash-OFDM and WiMAX would behave in mobile environments. It is also probable that the prices of new technologies will come down eventually. Cost estimates derived from current information would be inaccurate, as that information would be founded on uncertain technical assumptions.

Finland's meager population reflected in the numbers of train passengers is problematic as far as the cost structure is concerned. Although passenger numbers have grown steadily for the past few years, their number in Finland is just fraction of the numbers in other European countries. Small number of passengers is a cause of concern with regard to on-train broadband. It makes no financial sense for VR to invest large amounts of money on a broadband system, if it remains uncertain whether the investments could be recovered. It is possible to approach the issue in a business-like manner by charging the users an access fee which is additional to train ticket payment, but the amount of money changing hands would naturally be proportional to the number of passengers.

It is possible to establish on-train broadband, but for the time being, with the equipment prices as high as they are currently, it is still too expensive. Broadband access as a normal business proposition is not a likely scenario in the coming years. Technological developments and decreasing costs will sooner or later enable the introduction of broadband for fast-moving trains in Finland as well. Among the passengers there is a clear demand for broadband access, but unfortunately economic factors weigh more than their preferences. It must be kept in mind also that the presented solution combining many technologies still needs additional definition by experimentation before broadbanding can really start. The feasibility study group will continue its activities with technical experiments in the autumn 2005.